

## 2019 USCMS Report

### Introduction

The 2019 US Climate Modeling Summit (USCMS) was organized by Steven Pawson (NASA GMAO) and Gavin Schmidt (NASA GISS). The USCMS is an annual activity, convened for the Interagency Group on Integrated Modeling (IGIM), which coordinates global-change-related modeling activities across the Federal Government, reporting to the USGCRP. Along with the center leads of the six major federal global weather and climate modeling groups (DoE, NASA-GISS, NASA-GMAO, NOAA-EMC, NOAA-GFDL, and NCAR), the meeting attendees include members of the USGCRP and a range of program managers and others from the federal agencies.

The 2019 USCMS was generously hosted by SSAI at their Headquarters in Lanham, MD, on April 3-4, 2019. The six groups were represented by the principals as listed:

- DoE – Dave Bader and Ruby Leung
- NCAR – Gokhan Danabasoglu and Jean-François Lamarque
- NASA GMAO – Steven Pawson, Andrea Molod, and Bill Putman
- NASA GISS – Gavin Schmidt and Susanne Bauer
- NOAA EMC Hendrik Tolman and Vijay Tallapragada
- NOAA-OAR-GFDL – V. Ramaswamy and John Dunne

### Modes of Variability Workshop (April 3)

The first day included a focused workshop on “Modes of Variability and their Representation in Models” which was attended by about 20 invited scientists, in addition to the USGCRP leadership team, the group leads and staff from the program offices. The themes of this meeting were to examine the modes (MJO, AO/NAO, SAM, QBO, ENSO, AMO, IPO, ...) and their representation in models, with focus on:

- Structure and dynamics of the modes, as represented by our models
- Key physics for the modes in the models (recent advances, shortcomings, ...)
- Initialized and free-running – what we learn
- Sensitivity of modes to climate change

The meeting was partitioned into three themed sessions of presentations, that included invited speakers and shorter talks by group members, which were followed by breakouts into three discussion groups with the same themes. A session chair and rapporteur covered each group. The themes, along with the details of these sessions, are summarized next.



## Theme 1. Forced and Free Tropical Modes

Chair: Vijay Tallapragada

Rapporteur: Ruby Leung

Invited Speakers:

- Clara Orbe (NASA GISS) – The Quasi-Biennial Oscillation: Current Understanding and Challenges in Model Development
- Ángel Adames-Corraliza (University of Michigan) – The Madden-Julian Oscillation. What have we learned from it and where is our field heading?

Contributed presentations:

- Ming Zhao (NOAA/OAR-GFDL) – Simulations of the MJO in GFDL's New Generation GCMs and a Mechanism Study Using Fully Closed Moist Static Energy Budget
- Amin Dezfuli (NASA GMAO) – MJO and Indian Ocean Dipole in GEOS Systems

Summary of Discussions – the major points are listed, based on Dr. Leung's notes.

### 1. Assessments of the present ability to represent these modes:

- QBO:
  - Our ability to simulate the QBO has improved in recent years
  - Some difficulty in simulating how far down zonal wind signals propagate, which may influence ability to simulate QBO-MJO connection
  - Dependence on GWD parameterization limits models' ability to simulate QBO response to warming
  - Sensitivity to vertically integrated momentum flux, so changes in convection parameterizations require retuning
  - Nonhydrostatic model may be helpful for simulating gravity waves and hence QBO
  - Limited understanding of volcanic forcing on QBO behavior
  - Limited understanding of the QBO disruption that occurred in 2016 (it was not well predicted)
- MJO:
  - Improvements shown from CMIP3 to CMIP6
  - Previous models had to give up good simulation of mean state or good simulation of MJO but new models yield good simulations in both
  - **Need to understand why CMIP6 models are improved in MJO simulations – comparison of CMIP5 and CMIP6 simulations to understand changes that led to improvements**
  - **Need to better understand what aspects of radiation, mean moisture, and coupled processes are important for MJO and its representations in models – model comparison using mechanism denial experiments**
  - **Review paper to synthesize understanding of MJO and status of MJO modeling**
  - Why some models have a trade off between Kelvin waves and MJO?



- IOD:
  - Limited understanding of MJO-IOD interactions

## 2. Establishment of present uncertainties:

- QBO:
  - Metrics for QBO are less ambiguous as zonal winds are relatively well defined
- MJO:
  - No agreed upon definition of MJO (e.g., are there non-propagating MJO? Are large Kelvin waves MJO-like?)
  - Need a formal definition before one can establish common diagnostics
  - **Suggest developing a bare bone definition of MJO and then add details**
- IOD:
  - Some ambiguity in using REOF vs. EOF, detrended vs. not detrended data

## 3. Some potentially useful collaborative studies would be:

- QBO:
  - GFDL configuration of nonhydrostatic model improvement should be tested with other models
  - Participate in QBOi – intercomparison of QBO in chemistry models including climate simulations and projections and forecasts
  - **There are limited QBO diagnostics in current diagnostic packages**
- MJO:
  - Participate in GASS activities
  - Be informed about MJO Task Force activities (Maloney and Waliser)
  - Produce very long runs to study how multi-decadal modes influence MJO
  - **MJO diagnostic packages need updating to include more newly developed diagnostics**
  - Develop common definition and validation tool (e.g., NCAR MET+)

## 4. Leverage each group's strengths:

- 30-yr GEFS reforecast (5 members of 35 days) will be available by end of September together with new reanalysis data at 25 km resolution for analysis of MJO
- **Develop integrated diagnostic packages currently supported by NOAA, NSF, NASA, and DOE**

## Theme 2. Extratropical Modes and Teleconnections

Chair: Gokhan Danabasoglu

Rapporteur: Andrea Molod

Invited Speakers:



- Andrea Lang (University of Albany) – The NOAA Subseasonal-to-Seasonal (S2S) Prediction Task Force – with a Focus on Stratospheric Pathways for S2S Forecast Skill
- Siegfried Schubert (NASA GMAO) – A Systematic Approach to Assessing and Improving the Simulation of the Leading Modes of Climate Variability

Contributed presentations:

- Jessica Meixner (NOAA/NCEP EMC) – A Coupled Model for Subseasonal to Seasonal Forecasting
- Nathaniel Johnson (NOAA/OAR-GFDL) – Progress and Challenges in the S2S Prediction of Extratropical Teleconnection Patterns

The presentations and discussion are summarized, based on Dr. Molod's notes.

1. Summaries of the presentations:

- Andrea Lang, described her work assessing teleconnections in models, with some emphasis on stratospheric impacts on the troposphere, including effects of the QBO on modulating the teleconnections. The work of the Stratospheric Network for the Assessment of Predictability were introduced.
- Siegfried Schubert demonstrated a technique using bias correction, based on MERRA-2 analysis increments, applied at model run time. Compared to prior results using a similar approach, this method is now showing promise, with improvements in: subseasonal modes in boreal summer, which are due to quasi-stationary Rossby waves guided by the subtropical jet; (b) interannual variations in boreal winter circulation and ENSO in the coupled system.
- Jennifer Meixner described ongoing work to develop a coupled model in EMC, bridging the gap between GFS weather and CFC seasonal work. Testing involved sunning ensemble forecasts over seven years, and results indicate improvements in ENSO phases, the MJO, and sea-ice extent compared to their older models.
- Nathaniel Johnson described the progress and challenges of S2S prediction of extratropical teleconnections at GFDL. SubX experiments with FLOR show the most predictable modes are in the northern hemisphere in DJF; ENSO, the Eurasian mode and NAO have predictive skill beyond five weeks

2. Main outcomes of the discussions:

- Action item: the vertical resolution/upper boundary may be examined using coordinated experiments, to assess whether the QBO modulation of atmospheric teleconnections can be simulated realistically. Recommended set of common diagnostics should be done in-house. This work would inform the SPARC SNAP



(Stratospheric Network for the Assessment of Predictability) group (Andrea Lang will coordinate).

- A topic for discussion - TBC and interest is use as diagnostic tool and to see if increments have overlap
- The proper use of AI was emphasized and was proposed as topic for next year's theme meeting?

### Theme 3. Representations of the Modes in CMIP Models

Chair: Gavin Schmidt

Rapporteur: John Dunne

#### Invited Speakers:

- Peter Gleckler (DoE LLNL) – Quantifying the agreement between observed and simulated extratropical modes of interannual variability: A first look at CMIP6 results
- John Fasullo (NCAR) – Recent Advances and Remaining Challenges in Simulating Modes of Variability in CESM and CMIP Models

#### Contributed presentation:

- Luke von Roedel (LANL) – Modes of Variability in E3SM

The main points are outlined here.

#### 1. Summaries of the presentations.

- Peter Gleckler presented an analysis of extratropical modes analysis in CMIP5, showing EOF analyses of NAO, NAM, PNA gives dominant season in DJF, while SAM gives mild dominance in JJA. He showed that the pattern correlation of first EOF with observations can sometimes be bad when the second EOF is good. In terms of amplitude, they see little variation between ensemble members of individual models and an overactive in NCAR and GFDL in the season following the dominant season. For the emerging CMIP6 models, there are many improvements but overall the results are mixed for some modeling centers from CMIP5 to CMIP6. Questions: (i) Observational uncertainty in HADSLP about the same as the models encouraging that the models are butting up against the observational error in the dominant season. (ii) What are the synergies between the process level metrics and the overall performance metrics



- John Fasullo examined Tropical modes of variability (ENSO, MJO, PDO). One issue is whether it better to look at both pattern correlations (EOFs) and RMS differences (amplitude) to understand the role of each mode on overall climate. Climate modes important for detection/attribution, key source of predictability, key question on climate change and role of extremes. NCAR Climate Data Guide includes discussion of strengths and weaknesses of observations. The NCAR Climate Variability Diagnostics Package ( CVDP) does model variability analysis. The NCAR Climate Model Analysis Tool (CMAT) does a PCMDI type “portrait plot” and correlation analysis to demonstrate that ENSO and PDO improvements linked to improvements in mean state. Questions: Process based diagnostics are also important; when models span the observed variance they supply a means of assessing emergent constraints.
- Luke von Roedel – The E3SM run at low resolution looking fairly good. Improvements not fully translating to improvements in the high-resolution version.

## 2. Synthesis of the discussions:

The group tried to figure out what paper on US center modes of variability could be accomplished on the IPCC AR6 timeframe of submitting a manuscript by December. The discussion began with the general philosophy that among the CMIP6 model development priorities, there is a general aspiration that improved model representation of known modes of variability and “getting the right answer for the right reason” on timescales for which we have adequate statistics will lead to improved robustness in all areas of climate modeling including the longer term sensitivity of climate to external forcing. The discussion revolved around an combination of model analysis of the GFDL, GISS, E3SM and NCAR CMIP6 models for ENSO/PDO by Fasullo, NAO, NAM, PNA by Gleckler, and MJO by Adames could be combined with reanalysis constraints from GMAO and NCEP. This analysis could then go beyond the purely descriptive and anonymous CMIP type analysis by iterating with and interrogate within the centers to diagnose process and configuration mechanisms explaining differences among forward models and between forward models, reanalysis, and observational products... The group also talked about aerosols and volcanoes a lot.

## Meeting of the groups (April 5)

Dr. Renu Joseph welcomed the group and gave an overview of the IGIM and its role. Following introductions around the room, there were brief discussions of the prior year’s focus workshops, highlighting results and progress, and then presentations by the rapporteurs of this year’s “Modes” workshop. This all progressed without great controversy.

The model groups presented their major progress over the past year.





Two of the important discussions among the groups were in the realm of growth of high-performance computing to future architectures and the roles of AI/machine learning in our field.

- It is widely recognized that continued success in global modeling will depend implicitly on the groups being able to adapt to new compute platforms, because of the breakdown in Moore's Law that prevents continued growth capacity in CPU-based machines. Near-term options are likely to be GPU-based, as already being implemented in DoE environments.
- The importance of AI-based techniques for model development and data analysis were discussed quite intensively, not least because this arose as one of the two viable contenders for a theme for the 2020 workshop. Opinions were laid out that AI techniques have not yet led to systematic advances in model parametrizations (due to physical realism and computational restrictions), although there are signs of success in data analysis. The lack of unanimous support and the uncertainty about how mature the field is (with many workshops planned) led to a compromise that IGIM would include some AI-based seminars in their presentations for 2019-2020.

Major outcomes:

- A proposal will be written and submitted for partial funding to NASA and DoE; Gavin Schmidt will coordinate the team. The proposal will serve to coordinate work on model analysis across the modeling centers and will include contributions from academic groups
- The 2020 meeting will include a one-day workshop on "aerosol-cloud interactions" that will be chaired/co-chaired by Susanne Bauer/
- The IGIM will coordinate with the USCMS group in order to arrange presentations by experts in AI/machine learning in their monthly sessions; Dave Bader, Bill Putman, and (who else – was it Hendrik?) will liaise with IGIM to help select those speakers.

